Session No. 6

Course Title: Hazard Mapping and Modeling

Session 6: Modeling Flood Hazards

Time: 4 hrs

Objectives:

6.1 Clarify the nature of flooding as a hazard and its impacts.

6.2 Explain the factors that influence the nature and characteristics of flooding

6.3 Explain how flooding is measured Explain the development of risk assessment of flood hazards and its relation to the National Flood Plain Management Program.

6.4 Discuss the development of assessments of risk for flood hazards in the United States and the National Flood Plain Management Program.

6.5 Provide examples of models used in examining the risk of floods in the National Flood Plain Management Program.

6.6 Explain the elements of a Flood Insurance Study (FIS).

6.7 Explain the elements of a FIRM (Flood Insurance Rate Map) and how to use a FIRM to determine the risk of flooding for a specific piece of property.

6.8 Clarify the capabilities of HAZUS-MH Flood program.

Scope:

This session provides an introduction to the nature and extent of flooding as a natural hazard and its social, economic and environmental impacts. Modeling flood hazards will be examined to identify the type of information needed to characterize the depth and area affected by floods. The role of flood modeling in the National Flood Insurance Program will be discussed and how to read a Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM). Finally, the session will examine the HAZUS-MH Flood software and how it can be used to characterize the social, economic and environmental impacts from flood hazards.

Readings:

Student Reading:

Abramovitz, Janet (2001). Unnatural Disasters. Linda Starke, Editor. Worldwatch Paper 158. Washington, DC www.worldwatch.org

FEMA (1997). "Hydrologic Hazards." *Multi Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy*. Washington, DC. (pages 135 – 147) http://www.fema.gov/fhm/ft_mhira.shtm

O'Connor, Jim E. and John E. Costa (2003). *Large Floods in the United States: Where They Happen and Why*. Clarify its social, economic and environmental impacts. U.S. Department of Interior, Reston, VA. (ISBN 0-607-89380) http://water.usgs.gov/pubs/circ/2003/circ1245/

Wahl, Kenneth L., Wilbert O. Thomas, Jr., and Robert M. Hirsch (1995). "Stream-Gauging Program of the U.S. Geological Survey," U.S. Geological Survey Circular 1123, Reston, Virginia, 1995, By. http://water.usgs.gov/public/realtime.html

Instructor Reading:

Abramovitz, Janet (2001). Unnatural Disasters. Linda Starke, Editor. Worldwatch Paper 158. Washington, DC www.worldwatch.org

FEMA (1997). "Hydrologic Hazards." *Multi Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy*. Washington, DC. http://www.fema.gov/fhm/ft_mhira.shtm

FEMA (2003). *HAZUS-MH Riverine Flood Model Technical Manual*. Washington D.C.

O'Connor, Jim E. and John E. Costa (2003). *Large Floods in the United States: Where They Happen and Why*. Clarify its social, economic and environmental impacts. U.S. Department of Interior, Reston, VA. (ISBN 0-607-89380) http://water.usgs.gov/pubs/circ/2003/circ1245/

Wahl, Kenneth L., Wilbert O. Thomas, Jr., and Robert M. Hirsch (1995). "Stream -Gauging Program of the U.S. Geological Survey," U.S. Geological Survey Circular 1123, Reston, Virginia, 1995, By. http://water.usgs.gov/public/realtime.html

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General Requirements:

Handouts #1-1 and 1-2

Power point slides are provided for the instructor's use, if so desired.

It is recommended that students with little or no knowledge of flood hazards acquire a general overview of this hazard. Websites for materials relating to these are listed at the session's conclusion. In addition, the FEMA publication "Multi-hazard: Identification and Risk Assessment Report," which is a student reading for this session, provides an excellent introduction to flood hazards. FEMA (1997). "Hydrologic Hazards." *Multi Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy*. Washington, DC. http://www.fema.gov/fhm/ft_mhira.shtm

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Objective 6.1 - Clarify the nature of flooding as a hazard and its impacts.

Requirements:

Provide a general overview of flooding as a hazard and why it is so critical to understand the nature and extend of flooding in a local community.

Review the reference by Jim E. O'Connor and John E. Costa (2003). Large Floods in the United States: Where They Happen and Why. U.S. Department of Interior, Reston, VA. (ISBN 0-607-89380) http://water.usgs.gov/pubs/circ/2003/circ1245/

The USGS Circular 1245, *Large Floods in the United States: Where They Happen and Why.* Summarizes the locations and magnitudes of large flows recorded by the gage stations in the United States. It shows the locations of large floods and describes some of the climatologic and topographic factors that contribute to large floods. The source of data for this document is the "peak flow files" maintained as part of the USGS National Water Information System. This data is maintained for each stream flow gage station and includes values for the largest instantaneous discharge (peak flow) for each year from October 1 to September 30). These measurements do not account for or signify the damage caused by floods, but simply indicate the maximum volume of water passing the gage station during the peak of the flood. This gage "peak flow data" is one of the inputs into FEMA's HAZUS-MH (Hazards United States – Multi-Hazard) flood program. (O'Connor, 2003).

Remarks:

Class Activity: Where do floods occur in the United States? What conditions cause these floods?

Distribute Handouts #1 and 2. Divide the class into small groups and ask the groups the following two questions:

1. Identify where **large floods** occur in the United States and the type of hazard event that caused them.

2. Do large floods occur in areas that you would expect?

I. Nature of **Flooding**

A. A **flood** is a natural event for rivers and streams.

B. Flooding results from **excess water** from snowmelt, rainfall, or storm surge accumulates and overflows onto the banks and adjacent floodplains.

C. A flood is any relatively **high stream flow** that overflows the natural or artificial banks of a stream.

D. It is considered a **temporary condition** of partial or complete inundation of normally dry land areas.

F. Flooding typically results from **large scale weather systems** generating prolonged rainfall or on-shore winds.

G. Hundreds of floods occur each year, making it one of the **most common hazards** in the United States.

H. Floods occur in **all 50 states**, even in extremely dry areas of the U.S.

I. A large amount of rainfall over a short time span can result in **flash flood** conditions even in dry areas such as Arizona (FEMA 1997).

J. Other causes of flooding include locally intense thunderstorms, snowmelt, ice jams and dam failures.

K. A **small amount of rain** can also result in floods in locations where the soil is saturated from a previous wet period or if the rain is concentrated in an area of impermeable surfaces such as large parking lots, paved roadways, or other impervious developed areas.

II. **Financial Impacts** from Flooding

A. Floods are the **most chronic** and costly natural hazard in the United States, causing an average of $5 billion damage each year (Schildgen, 1999).

B. Despite advances in flood science and implementation of Federal hazard-reduction policies, **financial damage from flooding continues to escalate** (Pielke and Downton, 2000).

C. FEMA estimates that over 9 million households and $390 billion in property are **at risk** from flooding (FEMA 1997).

D. Damaging floods result when the volume of river flow exceeds levels of flood preparedness, either because flow is greater or longer than expected.

E. Property damage from floods results from a combination of the great power of flowing water, inundation by sediment-filed water, and the concentration of people and property along rivers (FEMA 2001).

F. The Great Midwest Flood of the upper Mississippi and Missouri rivers in 1993 provides a good example of the direct economic impacts from flood hazard in the United States. This flood was the **costliest flood** disaster in U.S. history. It affected nine Midwestern States.

G. Damage from this flood totaled as estimated $12 to 16 billion including agricultural losses. These floods were caused by a series of storms from April to September and affected parts of nine Midwestern States.

H. Between **$4 to $5 billion** of total damage is attributed to **agricultural losses** in the Midwest Floods (Interagency Floodplain Management Review Committee, 1994).

I. The economic losses associated with the Midwest Floods is attributed to actions by public and private sectors to expand agriculture, facilitate navigation and control flooding (Interagency Floodplain Management Review Committee, 1994).

J. The Worldwatch Institute determined that between 1985 and 1999, 37% of **the recorded natural disaster events** in the world were windstorms, **28 % floods**, and 15% earthquakes. Events such as fires and landslides accounted for the remaining 20% (Abramovitz 2001).

K. Economic losses from these disasters have reached **catastrophic proportions** measured in 1999 dollars, the $608 billion in economic losses during the 1990's was more than three times the figure in the 1980's, almost nine times that in the 1960's and more than 15 times the total in the 1950's (Abramovitz 2001 p.7).

L. According to the Worldwatch Institute, North America suffered 33% of the **economic losses** from all types of natural disasters from 1985 through 1999 despite the fact that the number of deaths during the period was low (1%). (See Figure 4 in Abramovitz 2001).

M. Early warnings and disaster preparedness have been a significant factor in keeping the death toll from being even higher.

III. **Fatalities** from flooding

A. On the average, **140 fatalities occur annually** as a result of flooding (Schildgen, 1999; FEMA 1999). Most injuries and deaths occur when people are swept away by flood currents (FEMA 2001).

B. Between 1985 and 1999, nearly 561,000 **people died throughout the world in natural disasters**, according to data collected by Munic Reinsurance. Only 4% of the fatalities for all natural disasters were in industrial countries. The company reported that 77% of the deaths were in Asia, 10% in South America, 4% in Africa and Central America, 2 % in the Caribbean, and over 1% each in Europe and North America.

C. The Worldwatch Institute determined that half of all **deaths** from natural disasters were due to floods. Earthquakes were the second biggest killer, claiming 169,00 lives. According to the Worldwatch Institute, the United States has only a small portion of fatalities from natural disasters when compared with the rest of the countries of the world (Abramovitz 2001).

D. Fatalities associated with flooding are not all a result of drowning. According to the Chinese government, 90% of the 30,000 deaths from floods in 1954 were a result of **communicable diseases** like dysentery, typhoid, and cholera that struck in the aftermath of floods. After the 1998 Yangtze flood, no such epidemics were reported. Advances in basic community services such as public water and sewerage services have reduced the number of deaths from natural hazards such as floods from being higher.

Question for Class Discussion

1. In what parts of the world do most fatalities from flooding occur? What explanation do you have for these fatalities?

Between 1985 and 1999, nearly 561,000 people died in natural disasters, according to data collected by Munic R. Only 4% of the fatalities were in industrial countries. The company reported that 77% of the deaths were in Asia, 10% in South America, 4% in Africa and Central America, 2 % in the Caribbean, and over 1% each in Europe and North America. The Worldwatch Institute determined that half of all deaths were due to floods. Early warnings and disaster preparedness have been a significant factor in keeping the death toll from being even higher.

Supplemental Considerations:

Objective 6.2 – Explain the factors that influence the nature and characteristics of flooding

Requirements:

This session explains the factors that influence the frequency of flooding and examines where flooding occurs in the United States. Students are encouraged to clarify how the nature of flooding differs throughout the United States and the world.

Remarks:

I. Factors influencing the nature and frequency of flooding.

A. **Impermeable Surfaces**: Excessive amounts of paved areas or other surfaces upstream or in the community can increase the amount and rate of water runoff. Development affects the runoff of storm water and snowmelt when buildings and parking lots replace the natural vegetation, which normally would absorb water. When rain falls in an undeveloped area, as much as 90 percent of it will infiltrate the ground; in a highly developed area, as much as 90 percent of it will run off.

B. Steeply sloped drainage areas (water resource regions and sub-regions, basins and sub-basins and watersheds): In hilly and mountainous areas, a flood may occur minutes after a heavy rain. These flash floods allow little or no warning time and are characterized by high velocities of water.

C. Constrictions: Re-grading or filling within or on the edge of floodplains obstructs flood flows, backing up floodwaters onto upstream and adjacent properties. It also reduces the floodplain's ability to store excess water, sending more water downstream and causing floods to rise to higher levels. This also increases floodwater's velocity downstream of the constriction.

D. Obstructions: Bridges, culverts and other obstructions can block flood flow and trap debris, causing increased flooding upstream and increased velocity downstream. Obstructions may also constrict the flow of water to cause backwater. This is a body of water in which the flow is slowed or turned back by an obstruction such as a bridge or dam, an opposing current, or the movement of the tide.

E. Debris: Debris from the drainage area, such as trees, rocks, and parts of damaged buildings, in creases the hazard posed by moving water. Moving water will float, drag or roll objects, which then act as battering rams that can knock holes in walls and further exacerbate the effects of debris.

F. Contamination: Few floods have clear floodwater, and the water will pick up whatever was on the ground within the floodplain, such as soil, road oil, farm and lawn chemicals, and animal waste.

G. Type of **soil and saturation**: Rainfall in areas already saturated with water will increase the runoff. Direct runoff refers to the runoff entering stream channels promptly after rainfall or snowmelt.

H. Velocity: Flood velocity is the speed of moving water, measured in feet per second. High velocities (greater than 5 feet per second) can erode stream banks, lift buildings off their foundations and scour away soils around bridge supports and buildings.

I. Topography is a contributing factor to flooding. It refers to the general configuration of a land surface or any part of the Earth's surface, including its relief and the position of its natural and man-made features. Topography is important in understanding flood hazards since it determines the direction and rate of the flow of water.

J. Ground cover refers to the presence and type of trees and vegetation in a drainage area. The capacity of the ground cover to absorb moisture either through leaves or roots impacts the amount of water transferred to a water feature. Water runoff is greater in areas with steep slopes and little or no vegetative ground cover.

K. The **size of the drainage area** has a significant impact on the nature and extent of flooding.

II. Areas of large floods.

A. Floodplains are lowlands, adjacent to rivers, lakes and oceans that are subject to recurring floods. It is a strip of relatively flat land bordering a stream channel that is inundated at times of high water.

B. Floodplains in the U.S. are home to **over nine million households**.

C. In the United States, about **3,800 towns and cities** of more than 2,500 inhabitants live in floodplains (Miller and Miller, 2000).

D. Puerto Rico and Hawaii both have many floods. These areas combine mountainous areas where moisture-laden tropical storms and hurricanes meet triggering precipitation (O'Connor 2003 p. 8).

E. In the continental United States, subtropical moisture from the Gulf of Mexico and the Atlantic Ocean trigger large floods in the Ozark Mountains of western Missouri and along the eastern edge of the Appalachians on the eastern seaboard.

F. The relationship between atmospheric conditions and geography are highly complex and each part of the United States is thus unique in the frequency of flooding.

Questions for Group Discussion:

1. What is flooding and what factors influence the development of flooding?

Hundreds of floods occur each year in the United States, including over-bank flooding of rivers and streams and shoreline inundation along lakes and coasts. Flooding typically results from large-scale weather systems generating prolonged rainfall or on-shore winds. Other causes of flooding include locally intense thunderstorms, snowmelt, ice jams and dam failures.

2. Many factors impact the nature and extent of flooding. Given your local and regional conditions, how do these factors impact flooding in your area?

Encourage the students to discuss the above factors that impact the nature and extent of flooding in their hometown or a region that they know. Stress that each part of the United States is different just as other parts of the world differ in how these factors influence the nature of flooding.

Class Activity: Examine the document in *Significant Floods in the United States During the 20th Century – USGS Measure a Century of Floods*. by Charles A. Perry. USGS Fact Sheet 024-00 March 2000. http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.024-00.html#HDR1

1. The map in this article identifies the most significant floods for the United States during the 20th Century. Note that they have categorized "significant floods" by type including: flash floods, regional floods, ice-jams, storm surge floods, dam failures and mudflow floods. Ask the class to identify the significant floods for their part of the United States. Were class members aware of the impacts from these flooding events?

2. What type of floods impacted the Northeastern Coast, Gulf Coast, or Western Coast of the United States?

3. Notice the Figure at the conclusion of the article and the dangers hazards associated with driving through floodwaters. Ask class members to comment on these dangers and what actions could be taken to reduce the risks associated with driving through flood waters.

> The slide clearly shows that deep floodwaters pose a significant danger to automobiles, especially in water that is over 2 feet in depth. Local communities should warn residents about these dangers and block roads that pose a risk of flooding. Community warning systems should also be used to identify where roads are covered with water and to avoid driving in these areas.

Objective 6.3 – Explain how flooding is measured

Requirements:

Handout #3: Image from: http://water.usgs.gov/wsc/map_index.html

Handout #4 "USGS River Gauge Hydrograph"

This session clarifies how flooding is measured. These concepts are critical in describing flooding events and why they occur.

Remarks:

I. Flooding is not a single event but actually may be measured by its range and frequency of occurrence

A. An **annual flood** is a type of flooding event that is expected to occur in any given year.

B. An annual flood is based on a statistical chance of a **particular size flood** (expressed as cubic feet per second of water flow) occurring in any given year.

C. It is important to recognize that there is actually a range of floods, other than just the 100-year flood.

D. A house located close to a flood source might experience some level of flooding every 5 to 10 year. The level or depth of flooding is determined by the probability.

E. The **percent annual chance of floods** or flood frequency is estimated based on many factors including watershed and climatic characteristics or water shed models, water surface elevations, and hydraulic models that reflect topographic characteristics.

F. **Flood Frequencies** or the chance of a flood occurring at a specific location can be measured by plotting a graph of the size of known floods for an area and determining how often floods of a particular size may occur.

G. If at least 20 years worth of data are available through stream gauging, hydrologic and hydraulic models can be used to determine the statistical frequency of given flood events.

II. Measuring drainage areas and water features

A. The largest geographic reference to a drainage area is known as a **water-resources region**. It is a natural drainage area (basin) or hydrologic area that contains either the drainage area of a major river or the combined areas of a series of rivers.

B. In the United States, the USGS has designated 21 regions of which 18 are in the conterminous United States, and one each in Alaska, Hawaii, and the Caribbean.

Class Activity:

Distribute Handout #3 for discussion: Image from: http://water.usgs.gov/wsc/map_index.html

C. Water Resources Regions are broken up into w**ater-resources sub-regions.** This is a subdivision of a water-resources region. The 21 water-resources regions of the United States are subdivided into 222 sub-regions.

1. We often refer to these water-resources sub-regions as **watersheds or drainage basins** (which is the land area drained by a river or stream).

2. Used alone, the term "watershed" is ambiguous and should not be used unless the intended meaning is made clear.

3. A **drainage area** denotes the divide separating one drainage basin or area from another.

4. Over the years, the use of the term “watershed” also signifies drainage basin or **catchment area**.

5. The term drainage divide, or the highest ground in a drainage area, is used to denote that there is a boundary between one drainage area and another.

Class Activity: Go to the USGS Web site http://water.usgs.gov/wsc/map_index.html

1. Select the area you are located in the United States.

2. Examine the Water resources region and sub-regions. On each of the maps showing the boundary of the hydrologic unit, select your area. The map will show water features and state and county boundaries to help you identify your area of interest.

3. Note that these Water Resources sub-regions are still quite large and the USGS divides these regions into hydrologic units. A numbering system is used to identify these hydrologic units. A further discussion of these units follows.

D. The USGS and EPA categorize water drainage areas and their elements.

1. **Hydrologic unit** is a geographic area representing part or all of a surface drainage basin as delineated by the U. S. Geological Survey on State Hydrologic Unit Maps.

2. Each hydrologic unit is assigned a hierarchical **hydrologic unit code** consisting of 2 digits for each successively smaller drainage unit.

3. Each sub-region includes that area drained by a river system, a **reach** of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area.

4. A s**tream reach** is a continuous part of a stream between two specified points.

5. Streams, rivers and other water features are **ranked** within a water resource sub-region.

6. **Stream order** refers to a ranking of the relative sizes of streams within water resources sub-region (watershed or drainage basin) based on the nature of their tributaries.

7. The smallest un-branched tributary is called **first order**, the stream receiving the tributary is called second order, and so on.

8. When using flood-modeling tools such as HAZUS-MH Flood, large water features are generally broken up into smaller segments to reduce the time to determine flood depths for a specific return period (event).

III. **Measuring flooding** in water features

A. **Hydrology** is the science that deals with the properties, distribution, discharge and circulation of water on the surface of the land, in the soil and underlying rocks and in the atmosphere. It also refers to the flow and behavior of rivers and streams.

B. All flood modeling programs including FEMA's HAZUS-MH need a discharge value for a water feature.

1. The **discharge value** is determined through hydrological analysis.

2. The **hydrology** of a water feature and its capacity to flood is measured **directly** by the USGS by the River Gage System and **indirectly** by statistical methods.

C. A **USGS River Gauge Station** measures the discharge for a particular site on a stream, canal, lake, or reservoir where systematic observations of water flow characteristics are obtained.

1. The is collected on a **real-time basis** since it is data collected by automated instrumentation analyzed quickly enough to influence a decision that affects the monitored system.

D. **Discharge** (a term related to the concept of "hydrology") characterizes the volume of water passing a point of a stream or river (river gauge station) or hydrologic unit per unit of time, commonly expressed in cubic feet per second, million gallons per day, gallons per minute, or seconds per minute per day. A major input to a flood modeling program is the discharge value or volume of water in a river or stream.

E. **Cubic feet per second** (cfs) is the typical unit of measure to express the rate of flow of surface water in open channels Cubic feet per second (cfs). One "cfs" is approximately equal to 7.5 gallons per second.

F. **Stage** involves the height of the water surface above an established point, such as in a river above a predetermined point that may (or may not) be at the channel floor.

G. The stage is measured in a **common reference** or datum plane – which is a horizontal plane to which ground elevations or water surface elevations are referenced (sea level).

H. The measurement of high water is a critical part of the modeling process for flooding events. A **Hydrograph** is a graph showing the variation of water elevation, velocity, stream flow, or other property of water with respect to time.

1. A hydrograph is provided for each USGS River Gauge to describe the properties of the water at that point in a water feature. It provides real time and historical values.

2. A hydrograph shows a **Mean discharge (MEAN)** of a stream during a specific period, usually daily, monthly, or annually.

Class Activity:

Hydrographs as shown in Handout #4 “USGS River Gauge Hydrograph” are available for water features in the United States where the USGS has a stream gauge station. The USGS provides information on current water resources conditions at: http://water.usgs.gov/waterwatch/

1. You may examine areas of high water in the United States by selecting the state of interest. Once the state map is shown, select an area of interest and look at the hydrograph for this water feature.

2. Identify and explain the value of the following to modeling flood hazards the following for this hydrograph:

a) Daily discharge value;

b) “Median Daily Streamflow” (discharge) based on 50 years of record. .

Objective 6.4 – Discuss the development of assessments of risk for flood hazards in the United States and the National Flood Plain Management Program.

Requirements:

The National Flood Insurance Program has developed from risk assessment efforts initiated by the Tennessee Valley Authority and the U.S. Army Corps of Engineers. A critical component of this program is the development of accurate flood maps. These maps are based on flood modeling for specific water features.

Remarks:

I. The Federal Government has been heavily involved in the **risk assessment** of flood hazards since the early 1960’s.

II. The Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers (USACE) were **early leaders** in this initiative to characterize the nature of flooding and understand their impacts.

III. Congress authorized the **National Flood Insurance Program** in 1968 with the enactment of the National Flood Insurance Act. The **U.S. Department of Housing and Urban Development** (HUD) was designated to administer the program.

IV. Under this legislation, **flood insurance** was made available at affordable rates to individuals as long as the local community adopted ordinances to regulate development in designated (mapped) flood hazard areas.

V. In 1983, HUD convened a group of experts to advise on the best **standard for risk assessment** and management. The group including federal agencies agreed on the 100 year or one percent annual chance of flood as the standard for floodplain management.

VI. This standard was considered to **represent a degree of risk and damage** worth protecting against, but was not considered to impose stringent requirements or burdens of excessive cost on property owners (FEMA 1983).

VII. The 100-year event represents a compromise between minor floods and the greatest flood likely to occur in a given area, that the highest recorded flood level reflects what has happened rather than what could happen, and that in many cases the 100-year flood level is less than the **flood of record**.

VIII. The **1-percent-annual-chance flood** (or 100 year flood) and the associate floodplain have been widely adopted as the common design and regulatory standard in the U.S. This 1-percent annual chance flood was established formally as a standard for use by Federal agencies with the issuance of Executive Order for Floodplain Management, E.O. 11988 in 1977.

IX. The flood having a 1-percent chance of being equaled or exceeded in any given year; also known as the **base flood** (and the NFIP as a **100-Year Flood**).

X. The 1-percent annual chance flood, which is the standard used by most Federal and state agencies, is used by the National Flood Insurance Program (NFIP) as the standard for floodplain management and to determine the need for flood insurance.

XI. The development of flood models and flood maps was considered by the NFIP as a primary means of reducing flood hazards. The flood maps would provide a basis for managing the development and use of flood prone areas and lead to a better understanding the magnitude and likelihood of large flows.

XII. A structure located within a special flood hazard area shown on a NFIP map has a 26 percent chance of suffering flood damage during the term of a 30-year mortgage.

XIII. In 1967, the U.S. Water Resources Council (USWRC) published Bulletin 15, A Uniform Technique for Determining Flood **Flow Frequencies**, (USWRC, 1967; Benson, 1967). The techniques were adopted by USWRC for use in all Federal planning involving water and related land resources.

XIV. This Bulletin has been updated several times with the latest version in 1982.

XV. Practically all government agencies undertaking **floodplain mapping studies** use flood flow frequencies as a basis for their efforts (Bulletin 17B IACWD, 1982).

XVI. Flood Flow Frequencies (Bulletin 17B IACWD, 1982) from this national initiative are used to determine **flood discharges** for evaluating flood hazards for the NFIP.

XVII. Flood discharge values are a critical element in preparing Flood Insurance Rate Maps. These maps show the elevations of the 1-percent –annual-chance flood along a water feature and within a flood zone. These elevations are refer to this as the "**base flood elevation**."

Question for Discussion:

Go to the FEMA Map Service Center Web site and download both examples of your area Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FIS).

http://store.msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1

For identifying a Flood Insurance Study use the FEMA website to find the study for your area.

http://store.msc.fema.gov/webapp/wcs/stores/servlet/StoreCatalogDisplay?storeId=10001&catalogId=10001&langId=-1&userType=G

Identify the date of the FIRM and FIS were prepared.

Do you believe that the maps and the study accurately reflect the nature of flooding in your area?

Given the factors that contribute to flooding in a local area, has there been residential, commercial or industrial development that might impact flooding?

Has there been major construction of roads or interstates, rail lines, or drainage improvements that could impact drainage in your area?

Objective 6.5. Provide examples of models used in examining the risk of floods in the National Flood Plain Management Program.

Requirements

The Corps of Engineers along with FEMA have used flood models to better understand the nature and extent of flooding in the United States. This section of the class provides a brief description of several models used in the National Flood Plain Management Program. The HECRAS flood modeling program is used extensively in the preparation of flood insurance rate maps. The results of HECRAS calculations may be used as a part of HAZUS-MH Flood.

Remarks

I. Modeling Flood Hazards

A. **HEC-RAS** (Hydrologic Engineering Center's River Analysis System) is as hydraulic model developed by the U.S. Army Corps of Engineers (1998).

1. It is used for calculating **water-surface profiles** for steady, gradually varied flow in natural or man-made channels. This model may be used for most water features in the U.S. that are characterized by flowing water.

2. It is a one-dimensional, steady gradually varied flow and unsteady flow water surface system to determine water surface profile calculations.

3. It determines surface profile calculations for a single river reach up to a network of channels.

4. It has the capacity to determine a profile for a riverine water feature and takes into account bridges, stream junctions, culverts, weirs, spillways and other structures in a flood plain.

5. It may be used to assess the change in water surface due to channel improvements or levees.

6. For the unsteady flow component, the program examines storage areas and connections between storage areas.

7. HEC-RAS also examines sediment transport in a one-dimensional environment over time (typically years or single flood events).

8. HEC-RAS is a primary input for FEMA's HAZUS-MH Flood Riverine advanced analysis for a water feature.

9. Terms used in HECRAS or HEC-2 flood modeling include (FEMA 2000):

    a. Mannings "n" Roughness Coefficient: The friction caused by earthen, vegetative, and or man-made surfaces within a floodplain impact the flow of water and thus its depth at a given point.

        (1) The roughness coefficient, n, is commonly used to represent flow resistance for hydraulic computations of flow in open channels.

        (2) The procedure for selecting n values is subjective and requires judgment and skill that is developed primarily through experience.

    b. Normal Depth: The depth expected for a stream when the flow is uniform, steady, one-dimensional, and is not affected by downstream obstructions or flow changes. This is the usual calculation that is utilized to determine Base Flood Elevations for property or structures in approximate (Zone A) areas.

c. Overbank: The area of a cross section that is found outside of the channel bank stations on either side of the stream channel.

d. Peak Discharge: The peak volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

e. Step-Backwater Analysis: A method used to analyze multiple cross sections. Water-surface elevations are determined for all sections based on a given discharge. The initial water-surface elevation is automatically determined by the normal depth method or by direct input of a water-surface elevation or depth.

f. Water-Surface Elevation: The height, in relation to the National Geodetic Vertical Datum of 1929 (or other datum) of floods of various magnitudes and frequencies in a floodplain.

g. Cross Section: A line developed from topographic information, across a floodplain at which a computation of flood flow has been made to establish a potential flood elevation. Cross sections are shown on the Flood Boundary Floodway Map, Flood Insurance Rate Map, and/or Flood Profiles of a Flood Insurance Study.

B. SWMM (Runoff) developed by the U.S. Environmental Protection Agency and Oregon State University (1997). The Storm Water Management Model (SWMM) is a comprehensive computer model for analysis of quantity and quality problems associated with urban runoff.

1. Both single-event and continuous simulation can be performed on areas (catchments) having storm sewers, or combined sewers and natural drainage, for prediction of flows, stages and pollutant concentrations.

2. The model can simulate all aspects of the urban hydrologic and quality cycles, including rainfall, snow melt, surface and subsurface runoff, flow routing through drainage network, storage and treatment.

3. Statistical analyses can be performed on long-term precipitation data and on output from continuous simulation.

4. SWMM can be used for planning and design. Planning mode is used for an overall assessment of urban runoff problem or proposed abatement options.

5. SWMM has been adapted by the New Orleans District of the Corps of Engineers to model flooding in the metropolitan area where extensive use of pumps remove water from drainage areas. SWMM was selected by the Corps of Engineers because of its capacity to model non-steady state dynamics. SWMM outputs may not be used in conjunction with the HAZUS-MH Flood Model.

B. Statistical models may also be used in the National Flood Insurance Program.

1. HEC FFA was developed by the Corps of Engineers in 1995 to perform a flood frequency analysis.

2. It performs flood-frequency analysis based on the guidelines delineated in Bulletin 17B, published by the Interagency Advisory Committee on Water Data in 1982. Estimate of flood flows having a given recurrence intervals or probabilities are needed for the design floodplain management and the design of hydraulic structures.

3. The program estimates annual peak flows on recurrence intervals from 2 to 500 years.

4. The program characterizes the magnitude and frequency of annual peak flows at gauging stations where data is observed. It is extremely useful in dealing with large sets of data over many years and where data is missing from a gage.

D. Other models are also used by engineering firms to examine the unusual characteristics of floodways, two dimensions state and unsteady dynamics. For more details on other models that may be used as part of the National Flood Insurance Program see FEMA's Internet site and search for Flood Hazard Mapping.

Objective 6.6 Explain the elements of a Flood Insurance Study (FIS)

Requirements:

Handout #5 "Flood Profile from FEMA FIS"

Any discussion of modeling and mapping of flood hazards should include some discussion of a Flood Insurance Study (FIS). A FIS is prepared after a local community formally agrees to participate in the National Flood Insurance Program. FEMA then authorizes the preparation of a FIS and Flood Insurance Rate Maps.

The following discussion of a FIS may be clearer to students if they examine a FIS for their local area. A copy of a local county FIS may be ordered for review by the class. Note that a local FIS may be obtained from the FEMA Map Service Center at:
http://store.msc.fema.gov/webapp/wcs/stores/servlet/StoreCatalogDisplay?storeId=10001&catalogId=10001&langId=-1&userType=G

Remarks

I. Elements of a **Flood Insurance Study**:

A. **A Flood Insurance Study (FIS)** is a report prepared by the FEMA that summarizes an analysis of the flood hazards in a community. The analysis used to prepare a FIS is also used to prepare a Flood Insurance Rate Map (FIRM), which is a map showing flood hazards in a community. The FIRM is the basis for floodplain management, mitigation and insurance activities in the NFIP.

B. To get copies of a FIS or a FIRM contact the FEMA Map Service Center (800) 358-9616 or by the web at http://www.msc.fema.gov/. Paper copies of both the FIS and FIRM may be obtained for a local community.

C. Sections of a FIS

1. **Introduction**: Identifies which communities are included in the study and explains that the study is to be used in setting flood insurance rates and floodplain management.

a. Notes the **legislation** that the study is enacted under, the names of study contractors who prepared the study, the date of the work performed and contact information for those involved.

b. Provides a summary of the **schedule** of the work done in the study.

2. **Area Studied**: This section identifies the scope of the study including the name of the water features studied and the methods used.

a. A **map of the area** is usually shown to explain what parts of the jurisdiction were included in the study.

b. A general **description of the community** including the population, average rainfall, temperature, soil types and near by communities.

c. Identifies the **causes of flooding** in the community or region and notes natural or man made features that impact flooding.

d. **Past floods** are noted and the location of stream gages in the study area.

e. Identifies any **man-made features** that impact flooding such as channels or waterways as well as levees, dams or non-structural flood control measures such as a local ordinance.

3. Eng**ineering Methods**: The type of hydrologic analysis is outlined including peak rates of flow or discharge rates in streams for 10, 50, 100, and 500 year flood events. Other information in this section includes:

a. **Sources of the data**, methods of analysis (such as mathematical equations, gage data analysis, discharge curves or rainfall runoff models).

b. Summary of **discharge tables** for the peak discharge flood events.

c. **Surface elevations** for other events such as 10, 50 and 500-year floods.

d**. Data** used in the Hydraulic analysis is provided including: cross section location, the date of the field survey, contour measurement interval, and date of topographic data used.

e. Rou**ghness coefficients** used in the study (commonly referred to as Manning's "n" values.

f. Starting water **surface elevation** (SWSEL).

g. **Methodologies** used to compute the flood elevations. (The most common methodology used to calculate flood elevations for a stream network is HEC-2 or HECRAS).

h. Th**e vertical datum**. (FEMA primarily uses the National Geodetic Vertical Datum (NGVD) or the North American Vertical Datum (NAVD)).

4. **Flood Plain Management Applications**: The FIRM shows the areas that would be inundated by a flood having a 1-percent annual chance (100-year flood) in some areas and flood having 0.2-percent annual chance (500-year flood). Floodways are defined and how it is to be used for floodplain management. A list of streams that have floodways is provided.

5. **Insurance Applications**: Areas on the FIRM are designated by zones based on the flood risk potential computed in the analysis.

6. **Flood Insurance Rate Map**: This section identified and defines all zones shown on a FIRM and provides a brief description of the purpose of the FIRM for flood insurance and floodplain management.

7. Other Studies: If other flood studies have been done in the area, comments are provided to clarify if the current study agrees or disagrees with the present one.

8. **Location of Data**: Identifies the FEMA Regional Office and the local community office that keeps a copy of the FIS (Community Map Repository).

9. **Bibliography**: Lists any references for the study.

10. **Revision**s: For some studies this section provides a brief overview of revisions to the FIS. Agency information that supported the revision is provided.

D. Other Data in a FIS

1. Flood Profiles: A **flood profile** is a graph reflecting flood elevations along the centerline of a stream. The profiles in the FIS show the 100 year flood event and also often show the profiles for 10, 50, and 500-year events. See Figure #3 below "Flood Profile from FEMA FIS."

2. Other information includes:

a. **Cross sections** shown on the flood maps

b. **Location of the streets** crossing the streams

c. Elevation of the **streambed**

d. Other hydraulic structures.

Class Activity: Distribute Handout #5: "Flood Profile from FEMA FIS" for discussion.

3. The flood profiles should be used to determine the precise base flood elevation for an area in the floodplain, rather than the FIRM, which the base flood elevations are rounded to the nearest whole foot.

Questions:

1. Explain the elements of a FIS and their importance in examining the flood hazards in a local community:

Although the FIS is a technical document, it is critical in understanding the nature of flooding in a community. First, identify the date of the study. If extensive development has occurred in the area or new roads or other construction projects could alter the flow of flood waters, the study could be very out of date and not reflect the true nature of flooding in the community. Note the type of modeling that was used to describe flooding and if engineering studies were done to identify flood zones. Engineering flood studies are quite costly and in many communities only a portion of the county is subjected to this type of analysis. It is quite common to have engineering studies conducted in portions of a county while other areas are not. The designation of "AE" is used to reflect flood zones which are based on hydraulic modeling. Base elevations for determining the first floor elevation of a structure are provided in these flood zone designated areas. Areas where engineering studies were not used to identify flood zones are given the classification of "A." No base elevation is provided in these areas.

2. Examine the Flood Profiles for the sample FIS in Figure #3. Identify the key elements of the profile and explain their importance to clarify the nature of flooding in a community.

Key elements of the Flood Profile include the elevation in feet of the water, normal stream elevation at specific points along the water feature, location of cross sections, and the location of specific man-made features such as bridges, roads, railroad crossings etc.

Objective 6.7 **Explain the elements of a FIRM (Flood Insurance Rate Map) and how to use a FIRM to determine the risk of flooding for a specific piece of property.**

Requirements:

The following discussion of a FIRM provides a basis for a broad based discussion of how we use the results of flood modeling. The design of the flood map was intended to communicate areas of risk to the general public and to public officials who administer the Flood Insurance Program at the local level. FEMA intended to make the maps useful and easy to understand. Efforts in the class should be made to determine if the maps are easy to read and understand. Do they convey the information on flood risks at a community level.

The following discussion of a FIRM may be clearer to students if they have a local FIRM to examine. Note that a local FIRM may be obtained from the FEMA Map Service Center at http://store.msc.fema.gov/webapp/wcs/stores/servlet/StoreCatalogDisplay?storeId=10001&catalogId=10001&langId=-1&userType=G

Handouts: Two Student Activities are provided to help students understand the nature of the Flood Insurance Rate Map (FIRM) and how to read the maps. Many students may not have seen an example of the FIRM that is shown on Handout #7. The instructor should utilize the copy of the sample FIRM Index and Map Handouts #6 and #7 for the students to review during this discussion.

Handout #6: Flood Map Index for a County / Parish
Handout #7: Flood Insurance Rate Map.

The session also encourages the students to download a FIRM from their local jurisdiction and determine what areas of their community are in a flood zone that would require the purchase of flood insurance under the National Flood Insurance Program.

Remarks

I. **Flood Insurance Rate Map** (FIRM)

A. **Terms** Related to FIS and FIRMs:

1. **Confluence**: a location where two streams or rivers meet.

2. **Contour**: A line on a map showing the elevation and slope of an area.

3. **Base Flood Elevation**: The height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum of 1929, the North American Vertical Datum of 1988, or other datum referenced in the Flood Insurance Study report, or depth of the base flood, usually in feet, above the ground surface.

4. **Datum**: FEMA's FIRMS reference the elevation datum used to compute flood elevations. In completing elevation certificates, the same elevation datum as that shown on the FIRM must be used to compute lot and or structure elevations and to compute flood elevations that are not given on the FIRM.

5. **Discharge**: The volume of water that passes a given location within a given period of time – usually expressed in cubic feet per second.

6. **Flood Insurance Study**: An examination, evaluation, and determination of flood hazards and if appropriate corresponding water-surface elevations. The resulting reports are used to develop Flood Insurance Rate Maps. (It is also known as a flood elevation study.)

7. **Flood Profile**: A cross-sectional drawing showing the contiguous cross sections along a stream, with ground elevations and potential flood elevations plotted.

8. **Floodplain or Flood-Prone Area**: Any land area susceptible to inundation by water from any source.

9. **Floodway**: Channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 100-year flood discharge can be conveyed without increasing the elevation of the 100-year flood by more than a specified amount (1 foot in most states).

10. **Zone AE**: Areas inundated by the 1-percent annual chance flood where water surface elevations or water depths are computed by hydraulic models.

11. **Zone A**: Areas inundated by the 1-percent-annual-chance flood for which flood elevations are not determined by hydraulic models are designated as Zone A. These are determined by study methods, which include depth-frequencies, slope-conveyance computation, cross sections, and inundation patterns of historic record. Since these are not based on hydraulic models, flood elevations are not provided.

12. **Zone X**: Areas outside the 0.2 percent annual chance of flood.

B. All FIRMS will include a title box, legend, and body.

1. **Title Block**: the community name, panel number (page number), date and other information necessary to identify the Flood Map panel.

2. **Legend**: The Legend provides information for identify the risk zones and or floodway on the map.

3. **The Body**: For an "index" the body displays the map contents such as primary features like major roads, corporate limits and other general landmarks that help to identify location. On a "panel" the body will show more detail than what is shown on an index, including secondary roads, bridges, and flood hazard information.

C. Major Map Elements of a FIRM

1. **Community Name**: The name of the mapped community such as a town, city, or county (parish) and the state. When the community is a county / parish, the words "Unincorporated Areas" often appear below the county name. This indicates that the incorporated areas in the county area not covered by the Flood Map. When the Flood Map covers the entire geographic area of the county, the words "and Incorporated Areas" appear after the county name.

2. **Community Number**: This is a six-digit identification number assigned to the mapped community. This number is also referred to as the community identification number (CID).

3. **Corporate Limit or County Line**: This identifies the jurisdictional limits of the community's regulatory authority over land development and building construction. In some states, an incorporated community may exercise extra-territorial jurisdiction over land development and building construction in areas beyond its corporate limits.

4. **Inset Note**: Identify what panel includes special areas on the map.

5. **North Arrow**: This arrow orients the Flood Map.

6. **Panel Limit Line**: The line reveals the extent of the area covered by each panel shown on the index.

7. **Panel-not-Printed Notes**: These notes identify the panels included in the Flood Map layout that are not printed and explain why they are not printed.

8. **Flood Map Index**: If a Flood Map is composed of more than one panel, an index is usually provided that serves as a guide to the information found on each map or panel.

Class Activity: Distribute **Handout #6:** Flood Map Index for a County / Parish" for discussion.

D. Types of Flood Map Indexes: There are three different types of indexes depending upon the community, Flat Flood Maps, Community Flood Maps and Countywide Flood Maps.

1. **Flat Flood Map** index cover communities that are mapped on 11” by 17” sheets. This index shows the outline of the community and the numbers and positions of the individual panels (sheets).

a. Contains a key to the various flood insurance risk zone designations and important notes to the user.

b. Effective date and dates of revision is shown on this map.

c. Community name and number will be shown on the title block.

d. Legend provides information on various flood insurance risk zones designations used in the map.

2. **Individual Community Flood Map Index**: This index range in size from 8 ½” by 11” to the larger 37 1/2 “ by 25 1/2 “ sizes. These index maps show the community boundary and the number and position of the individual panels. Individual Community Index Maps do not have a legend and general panel notes to the user.

3. Countywide Flood Map Index: Displays the entire county / parish and any incorporated areas. These maps may include more than one community. Community boundaries, identification numbers, and panel number are shown along with the numbers and position of individual panels. Non-flood prone communities are noted as non-flood prone.

E. Reading a Flood Map Panel

1. Elements of a Flood Map Panel (the first seven elements were noted earlier as Major Map Elements on a FIRM)

Class Activity: As the instructor discusses each element of a FIRM, identify the element on the sample FIRM shown in Handout # 7. Flood Insurance Rate Map (FIRM).

a. Community Name

b. Community Number

c. Corporate Limit or County Line

d. Inset Note

e. North Arrow

f. Panel Limit Line

g. Panel-not-Printed Notes

h. Area Not Included Label: Identifies areas that are in the panel but not in the jurisdictions of the community. *

i. Base Flood Elevation: For detailed study areas, this line and label indicates the water surface elevation of the base flood. A wavy line is used to indicate when the base flood elevation varies along a watercourse. When the base flood elevation is uniform across a large area, a label is used. *

j. Coastal Barrier Area: Coastal barrier symbols appear only on Flood Maps that contain coastal communities. These symbols identify undeveloped coastal barriers in the area. No new flood insurance coverage may be provided after specified dates for new or substantially improved structures in a Coastal Barrier Area. *

Class Activity: Handout # 7: "Flood Insurance Rate Map (FIRM)"

k. Elevation Reference Marks: These marks identify points where a ground elevation is established by survey. *

l. Floodplain Boundary *

m. Hazard Area Designation: These areas appear as dark and light tints. Dark tints indicate areas of greater flood hazard; light indicates areas of lesser flood hazard. *

n. Map Scale: Most scales are one inch on the map equals 500, 1000 or 2,000 feet on the ground. *

o. Panel Number:

p. Notes to User *

q. River Mile Marker: This marker identifies the distance in miles from a reference point on a river or other major watercourse. *

r. Stream Line: This line identifies the location of a watercourse. Narrower streams are usually shown by a single line, representing the

approximate location of the stream centerline. Wider streams are often shown by double lines, representing stream bank locations. *
s. Zone Designation: The zone designations indicate the magnitude of the flood hazard in specific areas of a community. *

t. Zone Division Line: This line separates Special Flood Hazard Areas with different zone designations and separates differing Base Flood Elevation in a coastal hazard area. *

u. Flood Insurance Risk Zone Label

v. Elements found on some maps:

w. Alpha-numeric Grid

x. Cross section symbol

y. Floodway boundaries

z. Floodway designation

aa. Map repository address

bb. Panel locator diagram

F. Using a FIRM to determine the risk of flooding for a specific piece of property.

Class Activity:

Scenario: You are considering buying a new home. Before you make a final decision, you want to know the potential risk that this house could be flooded. You need to know if the property is in a Special Flood Hazard Area (SFHA) and if it is the flood insurance risk zone designation and Base Flood Elevation that apply to the property.

i. Review the index for the community and identify which panel that covers the property.
ii. Identify the general location of your property and note the panel number.
iii. Obtain the appropriate panel and locate the address on the map. To find the specific location of the property, you may refer to a plat map of the property, the tax assessor's map, or the property description found on the property deed.
iv. Identify the Flood Insurance Risk Zone for the Property.
v. Occasionally, a property or building is shown in the SFHA on the map, but the property or building is higher than the BFE. This may be due to the limitations of the mapping. To be sure is a property of building

should be in the SFHA, a comparison between the elevation of the property or building and the BFE should be preformed. If the lowest elevation of the property or the lowest grade adjacent to the building (in some cases the lowest floor including the basement of the building) are below the BFE, the property or building are in the SFHA. If a property or building is inadvertently shown within the SFHA or if a property or building has been raised above the BFE; FEMA can amend or revise the maps with a letter that states the property or building is not within the SFHA. These letters are called Letter of Map Amendment (LOMA) or Letter of Map Revision based on Fill (LOMR_F). To make this determination you need to know the lowest lot elevation, or the lowest adjacent grade at the building and in some instance the lowest floor elevation (including basement). You may need to get an elevation survey of the property or building to determine its BFE.

vi. Identify the Base Flood Elevation at the Property. Note that BFEs shown on a Flood Map are only accurate to a plus or minus a half foot. If two BFE lines are on the property, you may estimate the BFE at the property by interpolating between the two base flood elevations. For an accurate BFE, you may refer to the Flood Profiles or Flood Elevations Tables in the FIS report.

vii. Some SFHAs do not have BFEs shown on the Flood Maps. These SFHAs are shown as zone A or zone V and were determined by approximate methods. Possible sources for obtaining a BFE in the area may be the community's planning, public works, or engineering departments. A registered professional engineer may also conduct an engineering analysis to determine the BFE at the site.

13. Digital FIRMs – DFIRM – the Next Generation: Digital Flood Insurance Rate Maps are being prepared in many communities. Some information from the current flood map is converted to a digital format. The maps may be viewed in a geographic information system (GIS) and potentially include multiple hazards. The maps may be viewed with other data such as digital elevation certificates and high-resolution photographs including bridges and culverts. The standard scale for a DFIRM is the USGS Digital Ortho Quads (DOQ).

Supplemental Considerations:

Questions for Group Discussion:

Objective 6.8 Clarify the capabilities and levels of analysis of HAZUS-MH Flood program.

Requirements

This part of the class provides an overview of the data requirements for the HAZUS-MH Flood program. The instructor should be encouraged to review the First Chapter of the Technical Manual of the HAZUS-MH Flood program for an excellent introduction to the purpose and capabilities of the program.

Remarks

I. In the early 1990's FEMA embarked on an undertaking to expand the Nation's capacity to estimate losses from major types of natural hazards, including earthquakes, floods, and severe winds.

A. This project was designated as Hazards United States (HAZUS) and is an integrated software package. Within HAZUS-MH there are separate modules for characterizing and estimating the losses from each hazard.

B. The Flood model methodology consists of two basic analytical processes including flood hazard analysis and flood loss estimation analysis.

C. The first type of analysis is a Level 1 Analysis or a "Basic Analysis"

1. This flood hazard analysis phase uses characteristics such as frequency, discharge, ground elevation to determine the spatial variation of the flood depth and velocity.

2. In the loss estimation phase, structural and economic damage is calculated based on the results of the hazard analysis through the use of vulnerability curves.

3. The outputs are in the form of reports and maps.

4. In the Basic Analysis, data is provided for estimating the nature and extent of flooding for each community in the U.S.

7. Data for estimating damage assessment from flooding is included with the software.

8. Estimates for estimating building losses are provided at the Census Block level for each community in the U.S.

9. Level 1 analysis is the simplest type of analysis requiring minimum input by the user. The flood estimates however are crude and are appropriate only as initial loss estimates to determine where more detailed analyses are warranted. Some refer to this type of analysis as "screening." USGS regression equations and gage records are used to determine discharge frequency curves.

D. Level 2 Analysis

1. The user modifies the local building inventory data to more accurately reflect the number of structures in a Census Block, their characteristics and value.

E. The Third Level or Advanced Analysis

1. The third level of analysis utilizes Hydraulic models to estimate the nature and extent of flooding in an area.

2. These models may have been used in the preparation of a FEMA FIRM and available from the U.S. Army Corps of Engineers, FEMA, or a FEMA contractor.

3. The Level 3 Analysis provides the basis for identifying specific mitigation steps that a local community might take to alleviate flooding and property damage.

a. The Level 3 Analysis requires more extensive flood hazard data rather than default data used in a Level 1 analysis. This analysis uses FEMA approved flood hydraulic and hydrology model results, and floodplain boundaries.

b. HAZUS utilizes stream cross-sections attributed with elevations computed by hydraulic models (HEC-RAS) or base flood elevation (BFE) lines from a FIRM.

F. HAZUS-MH Loss Estimation Methodology

1. Identify surface elevation contours using the USGS Digital Elevation Model files.

2. Determine the nature and extent of flooding for a water feature or a part of a water feature.

3. Compare ground surface with the flood surface to determine flood depth throughout the study area.

4. Estimate Losses

G. HAZUS-MH Outputs include:

1. Produce **hazard maps** showing the nature and extent of flooding utilizing a flood depth grid

2. Building stock loss including the building structure and the contents of the structure

a. Residential

b. Commercial

c. Industrial

d. Education

e. Government

3. Infrastructure damage to bridges, treatment plants etc.

4. Population impacts (casualties & shelter requirements)

5. Indirect economic losses (market sector recovery).

II. The HAZUS-MH Riverine and Coastal Flood model uses two forms of analysis to determine the depth, duration and velocity of water in a floodplain.

A. **Hydrologic Analysis**

1. HAZUS-MH Flood requires a **discharge frequency** reflecting the volume and velocity of the water for each stream / river feature (reach) in a study area.

2. **Flood discharge frequency curves**

a. Provide a simple method for estimating flood-peak discharges from data from the USGS River Gauge Stations.

b. Developed by the U.S. Geological Survey (USGS) for every State, the Commonwealth of Puerto Rico, and a number of metropolitan areas in the United States.

c. In 1993, the USGS, in cooperation with the Federal Highway Administration and the Federal Emergency Management Agency, compiled all of the then-current statewide and metropolitan area regression equations into a microcomputer program titled the National Flood Frequency (NFF) Program (Jennings and others, 1994.)

d. New or updated regression equations have been developed for most States since the initial release of NFF.

e. For areas where River Gauge Stations are not available, the discharge frequency is determined using USGS **regression equations** for the water feature or study region.

3. Stream flow may also be measured by USGS Stream Gauges

a. The data underlying most studies of flood magnitude and frequency in the United States are records of the U.S. Geological Survey (USGS) stream flow gages, which for the last 110 years have been collecting stream flow data at more than 23,000 locations (not all stations have been collecting **stream flow data** continuously and not all stations are now active).

b. Presently about 7,000 **stations** are active. Current and historical data for USGS river gauges in the US may be observed at its Website at http://water.usgs.gov

c. Stations monitor river stage (elevation of the water surface), which is then converted to **discharge** (flow volume per unit time) by use of a state-discharge rating curve.

d. Discharge values have been recorded by USGS at over 22,000 stream locations. Annual peak discharge values are recorded for each gage.

e. These **rating curves** are derived from and continuously updated by several measurements per year of flow discharge values and state-discharge rating curves. The largest flow of each water year (October through September), is compiled into the station's peak flow file (Connor 2003 page 5).

Class Activity:

The USGS maintains river gauge records (and historical data) for river gauges in the US. Determine the number of active USGS stream gauges in your area that HAZUS-MH would utilize in the "basic level 1 flood analysis) (see the USGS Website at http://waterdata.usgs.gov/nwis/rt).

- Select your state and determine to what degree is the USGS monitoring your drainage area?

- What geographic boundaries define your drainage area / water resources region and sub-region?

4. Discharge Values for measuring stream flow by **statistical methods**

a. The USGS has established the **National Flood Frequency Program** (NFFP) as a methodology for determining discharges in areas where there is not USGS gage.

b. Statistical estimates of flooding and the magnitude and frequency of flood-peak discharges and flood hydrographs are used for a variety of purposes, such as the design of bridges, culverts, and flood-control structures, and for the management and regulation of flood plains.

c. These estimates are used by HAZUS-MH Flooding in a Level 1 Analysis for locations where no observed flood data (such as the U.S.G.S. Stream Gages) are available.

d. New or updated regression equations have been developed for most States since the initial release of NFF. The new equations reflect the increased availability of flood-frequency data and advances in flood regionalization methods since the previous equations were developed. As a result, the newer equations generally provide more precise flood-peak estimates than the equations they supersede.

e. The FEMA HAZUS-MH Flood program utilizes the National Flood Frequency Program as a basis for their basic or Level I flood modeling and damage assessment.

f. These values are used in HAZUS-MH to characterize the magnitude of flooding in 200 hydrologic regions in the U.S.

B. Hydraulic Analysis

1. Hydraulic analysis determines **flood elevations** for a specific flooding event at a location on a water feature.

2. From this the **area flooded and the depth of flooding** may be determined by comparing the flood elevation along a water feature with land contours (Digital Elevation Model land elevations).

3. Hydraulic Analysis in HAZUS-MH Flood reflects an **advance analysis**

4. Data needed for Level III Advanced Analysis

a. **Cross sections** along a water feature.

b. **A water channel** (line in the GIS reflecting the path of the water feature)

c. An estimated **boundary** of the floodplain

d. **Friction factors**

e. **Discharge frequency** for the water feather

5. HAZUS-MH Flood calculates the **flood elevation** within the designated floodplain and the velocity of the water.

6. HAZUS-MH calculates the flood elevations for a given scenario (return period such as 50, 100 or 500 years) at each **cross section**.

7. Where cross sections are not available, water surface flood elevations are **interpolated**.

C. **Benefits** of HAZUS-MH

1. Identify **vulnerable areas** that may require planning considerations.

2. Assess level of **readiness and preparedness** to deal with a disaster before disaster occurs

3. Estimate potential losses from specific hazard events before or after a disaster occurs

4. Decide how to **allocate resources** for most effective and efficient response and recovery.

5. Prioritize mitigation measures that need to be implemented to reduce future losses.

D. **Applications of HAZUS-MH** in Emergency Management

1. Emergency Preparedness

a. Development of emergency **response plans**

b. Emergency response **exercises**

2. Loss Reduction

a. Mitigation assessment,

b. Mitigation measures, and

c. Mitigation programs.

3. Response and Recovery

a. Quick situation assessment

b. Operational response modeling.

c. Estimate direct and indirect economic losses.

E. Broad Based **Planning Team**

1. FEMA recommends that for the best results from the use of HAZUS-MH, the loss analysis will be performed by a **team** consisting of:

a. floodplain manager(s) - planners

b. structural engineer(s) engineering

c. economist(s) – finance officers

d. sociologist(s) from social service agencies

e. hydrologist(s) engineering

f. emergency planner(s)

g. public works personnel and

h. loss estimate users.

2. These individuals are needed to develop flood return periods or discharges of interest or concern, develop and classify building inventories, provide and interpret economic data, provide information about the local population, and to provide guidance on what loss estimates are needed to fulfill the user's goals.

3. The participation of at least one GIS specialist with some level of familiarity or expertise in data management and GIS would be very beneficial.

Supplemental Considerations

Questions:

1. What is the value of the USGS River Gauge Stations to understanding flood hazards?

Damaging floods result when the volume of river flow exceeds levels of flood preparedness, either because flow is greater or longer than expected or because of incomplete understanding of local hazards. A primary means of reducing flood hazards is by better understanding the magnitude and likelihood of large flows. Floods occur in all 50 states, even in extremely dry areas of the U.S. Flash floods characterized by rapid on-set and high velocity waters occur in areas of Arizona (FEMA 1997). The data underlying most studies of flood magnitude and frequency in the United States are records of the U.S. Geological Survey (USGS) stream flow gages, which for the last 110 years have been collecting stream flow data at more than 23,000 locations (not all stations have been collecting stream flow data continuously and not all stations are now active). Presently about 7,000 stations are active.

2. HAZUS-MH Flood allows the user to do a Basic (Level I Analysis) using the USGS River Gauge data and data from the National Flood Frequency Program and the results from HECRAS flood modeling in the Advanced Analysis (Level III Analysis). Do the results from HAZUS MH-Flood accurately reflect the event simulated under specified conditions?

Level I Analysis: The guidance documentation with HAZUS-MH Flood clearly states that a Level I analysis using the USGS River Gauge data and data from the National Flood Frequency Program is intended to provide an overview of the flood hazards for a county. This is generalized information for planning or screening purposes. The results help in the identification of areas in the jurisdiction that require detailed studies using the more advanced flood models such as HECRAS. FEMA stresses that the results of a Level I analysis should not be used to justify recommendations as a part of a county's flood mitigation effort.

Level III Analysis: The FEMA guidance documentation with HAZUS-MH Flood clearly encourages counties to utilize the Level III analysis to identify areas in the jurisdiction that hazard mitigation efforts should be focused. The Level III Analysis is based on widely used hydraulic models such as HECRAS. HAZUS-MH was designed to include the input from HECRAS and with the powerful tools in ArcGIS, produce a flood depth grid that could show the level of flooding in a jurisdiction.

3. Are limitations of the HAZUS-MH model stated in a clear straightforward manner?

The Technical Guidance Documentation with HAZUS-MH Flood clearly states the intended use of Level I and III Analysis. Further, the reports generated by HAZUS-MH provide a clear summary of the anticipated damage that results from the flood scenario (usually a 100 year flood event). HAZUS-MH also includes tools to allow a local jurisdiction to adapt the building inventory and other critical infrastructures so that the reliability of the analysis is enhanced.

4. Is the information resulting from the model output current and up to date when it is provided to the decision-maker?

The data inputs into HAZUS-MH Flood Level I – Basic Analysis are estimates of the discharge for a water feature. Users should not assume that the data is up to date and reflect current conditions. Even when using the more advanced models such as HECRAS, users should not assume that current conditions are reflected in the model. It is important that the user of a HECRAS have a copy of the latest Flood Insurance Study for the jurisdiction so as to see the date of the model was last revised. Further, some restudies by FEMA are completed for specific water features and not for the entire jurisdiction.

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